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LCLS Cu Cathodes Cleaning and Qualification

Workshop on High Quantum Efficiency
Photocathodes for RF Guns

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Motivations

- Copper is an historically-proven material for rf gun PCs
  - Easy to fabricate, forms end plate of half cell
  - Attains highest fields, with conditioning
  - Capable of sub-picosec emission
- Develop fabrication/chem cleaning schedule *ex-situ* to the gun that maximizes the quantum efficiency
- Explore the effect of *in-vacuo* cleaning on QE/surface finish

Realities

- Copper has problems
  - Only adequate QE (max of 1-2 x 10^{-4} @ 255 nm)
  - Needs UV
  - Other problems (thermal emittance, dark current, …)
- But..copper has history and was the conservative choice
- Focus on short-term improvements to the QE
  - Mechanical finishing (diamond-polish, diamond-flycut)
  - Chemical treatments (etch, us solvent degrease, brief rinse)
  - Vacuum treatment (heating, Ar^+ or H^+ ion scrubbing)

Ex-Situ Improvements

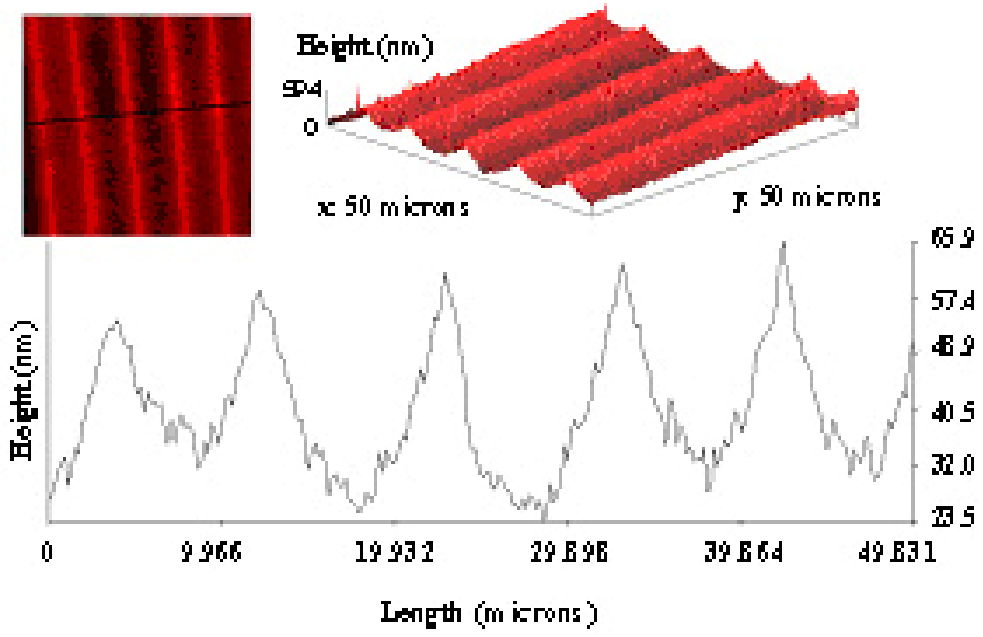
- Replace mechanical polishing and etching with diamond fly cutting followed by solvent degrease and/or vacuum fire

  - Removes lathe on-center machining defect
  - Bypass amorphous chemical etching residue layer
  - Eliminate etch pits that get "filled" by residue
  - Reduce overall contamination and particle level (XPS carbon contamination level < 10 atomic %)

- Store cathodes face down, in filtered dry N_2 atmosphere

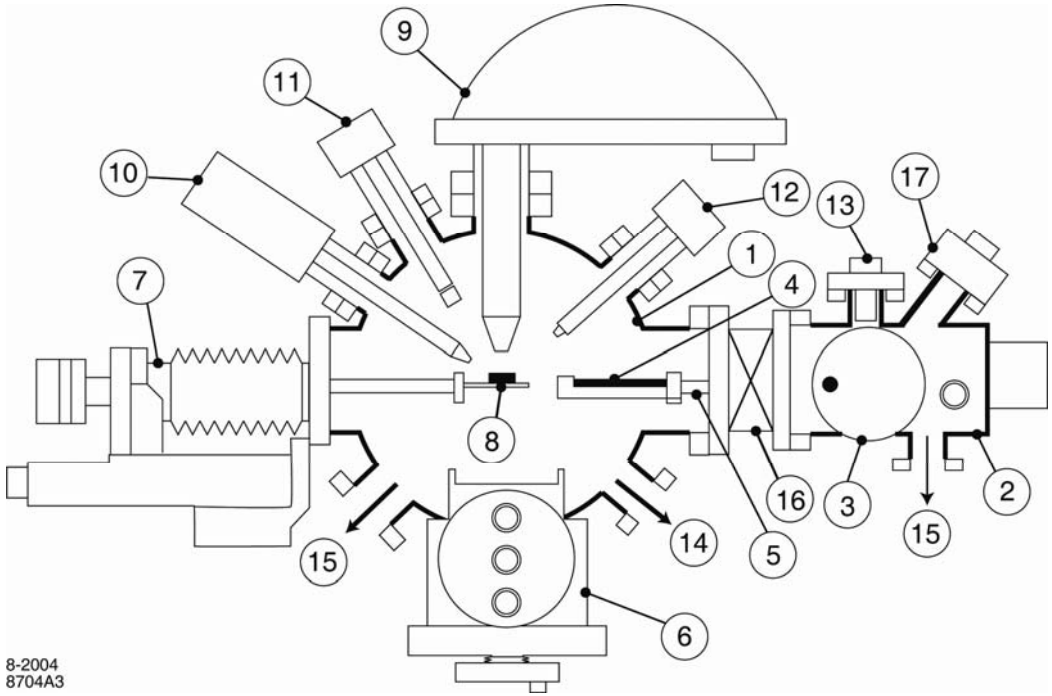
- Diamond finish does show very shallow repeating grooves

Surface Finish



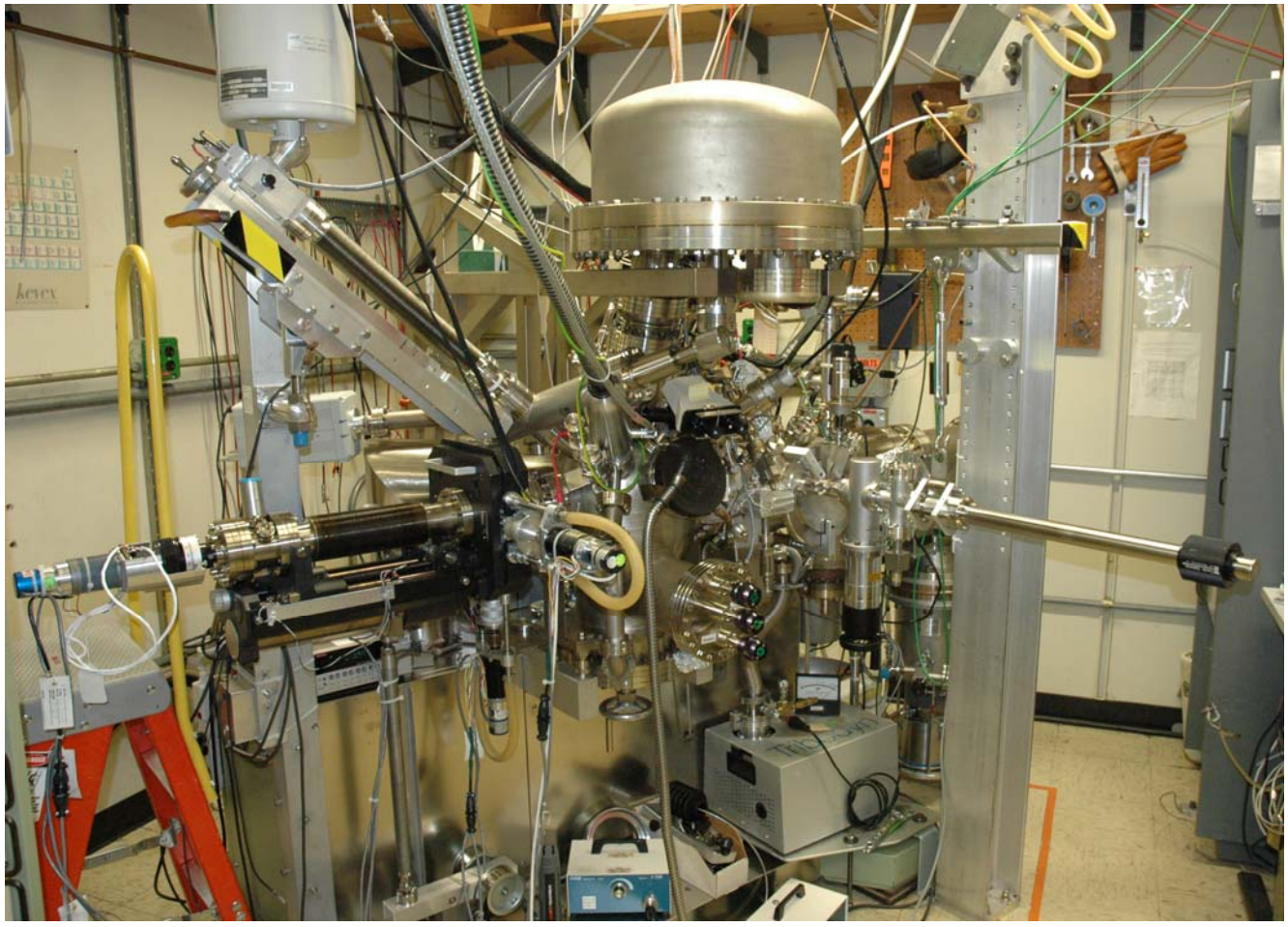
- Optical-quality diamond flycut OFE Cu
- Degrease only
- Measured in atmospheric atomic force microscope

Surface Physics R&D System

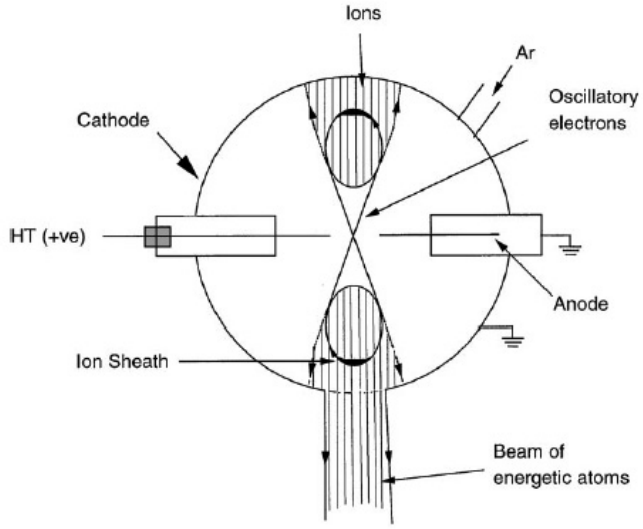


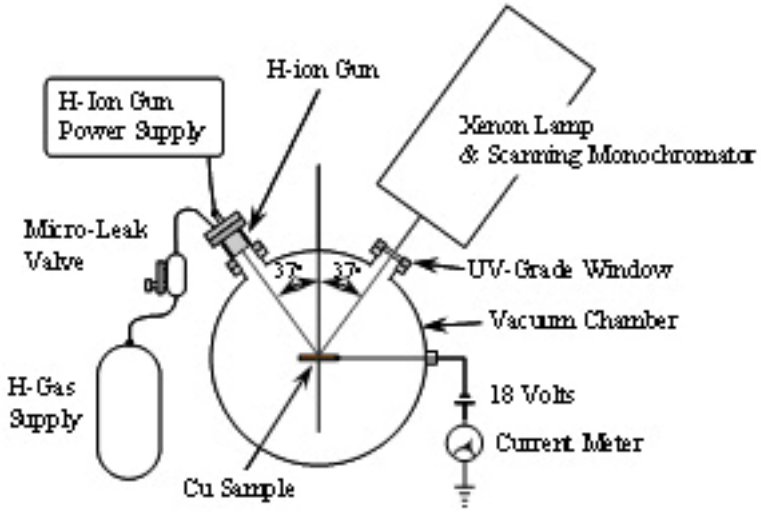
(1) Analysis chamber
(2) Loadlock chamber
(3) Sample plate entry
(4) Sample transfer plate
(5) Rack and pinion travel
(6) Sample plate stage
(7) XYZΦ manipulator
(8) Sample on XYZΦ
(9) Electron energy analyzer
(10) Al anode x-ray source
(11) SEY/SEM electron gun
(12) Micro-focus ion gun
(13) Cold cathode H^+ gun
(14) To RGA and gauges
(15) To vacuum pumps
(16) Gate valve
(17) UV light and monochromator

VG ESCALAB w/LoadLock and BabyLock



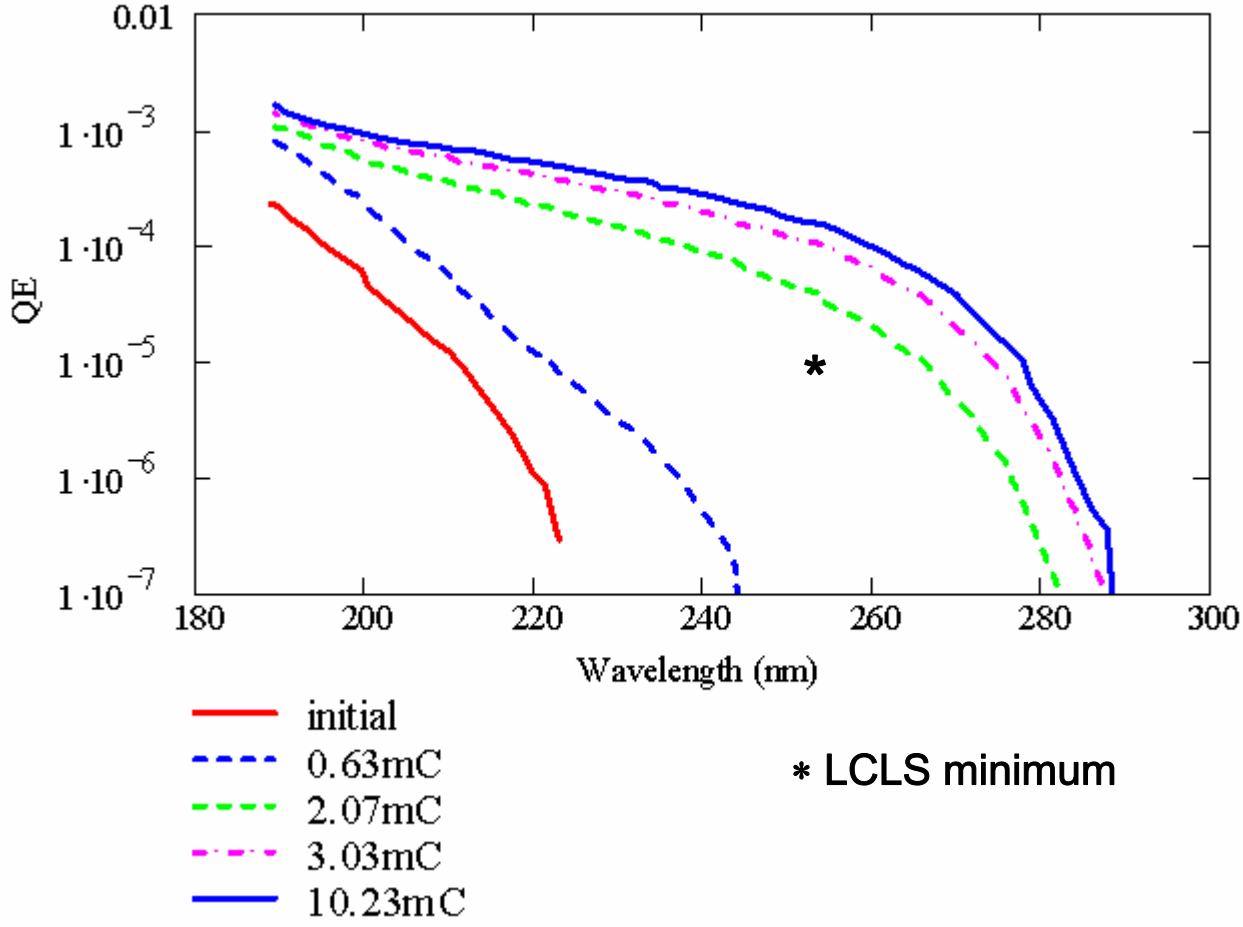
QE Measurement Setup





- Investigate coupons and SSRL GTF cathodes
- Ion-cleaning, saddle-field cold cathode, H^+ and Ar^+
- QE and XPS before/after cleaning

Hydrogen Ion/Atom-Cleaned Copper



In-Situ Improvements

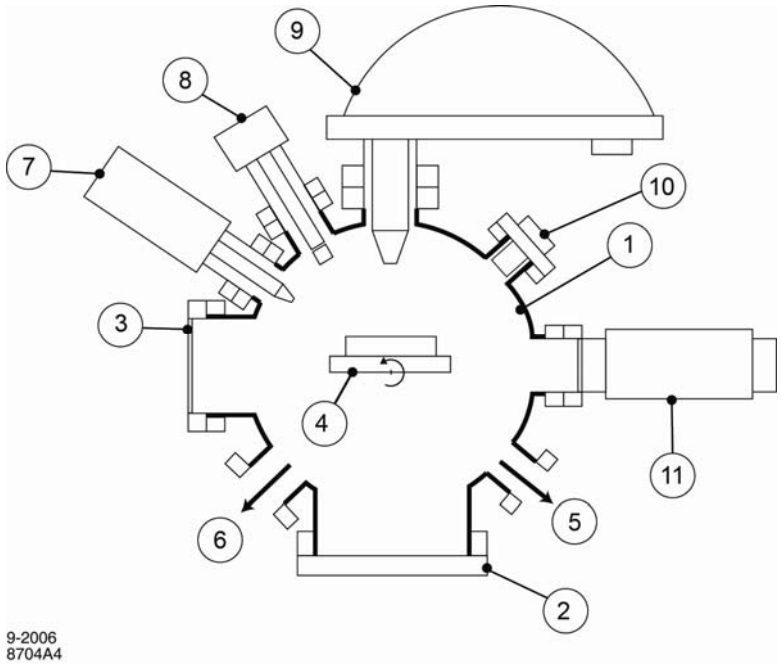
- Previous experience in cleaning GaAs polarized electron source wafers with hydrogen atoms was successful

  - H* produced in thermal "cracker" or microwave discharge
  - Ions compensate dopants, use only atoms
  - H* sources desorb gas from walls, need cold source
  - Saddle-field low energy gun produces ion and atoms

- Successfully clean copper at 1 keV H (ions + atoms)

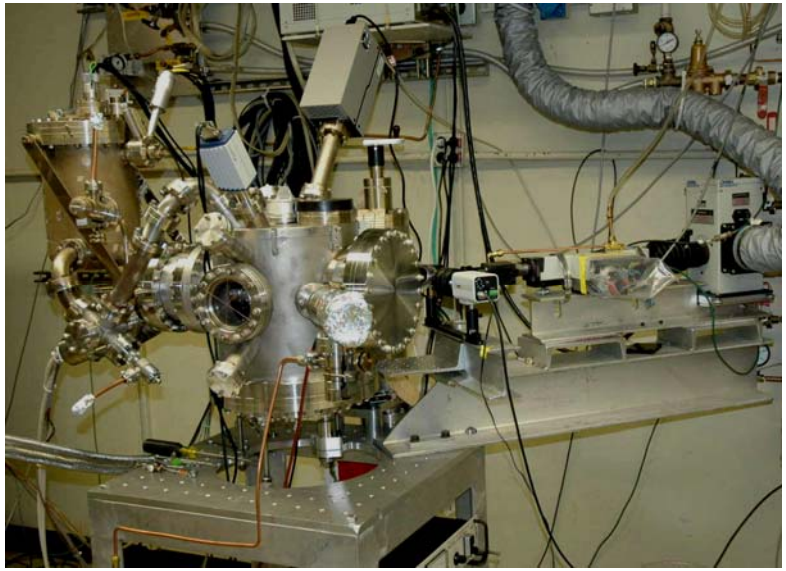
  - XPS carbon/oxygen as low as a few surface atomic %
  - QE's always converge to a maximum 1-2 x 10^{-4} @ 255 nm
  - Ar^{+} roughens the surface, H^{+} does not

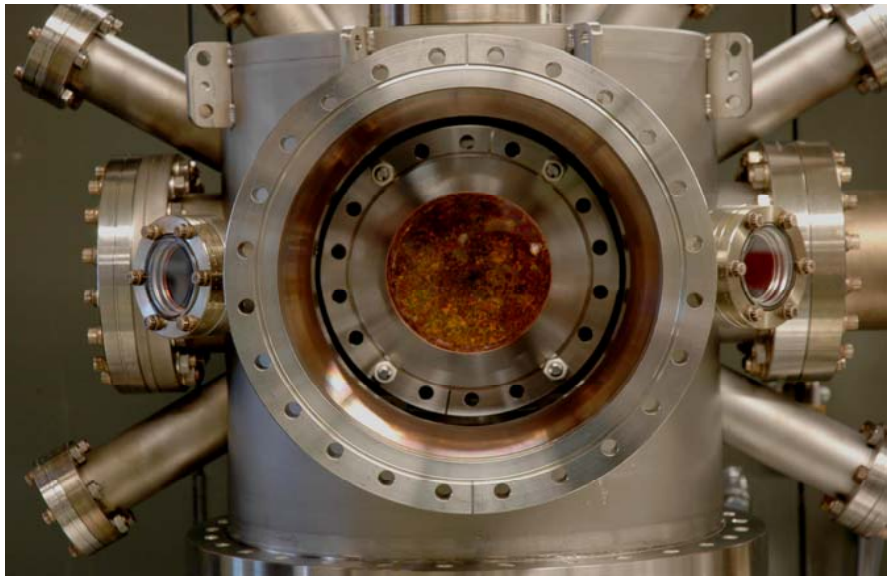
Cathode Qualification System (CQS)



(1) Vacuum chamber
(2) Cathode load port
(3) Viewport
(4) Cathode on rotation stage
(5) To RGA and gauge
(6) To vacuum pump
(7) XPS x-ray source
(8) AES/SEM electron gun
(9) XPS/AES energy analyzer
(10) Cold cathode H^+ gun
(11) UV light and monochromator

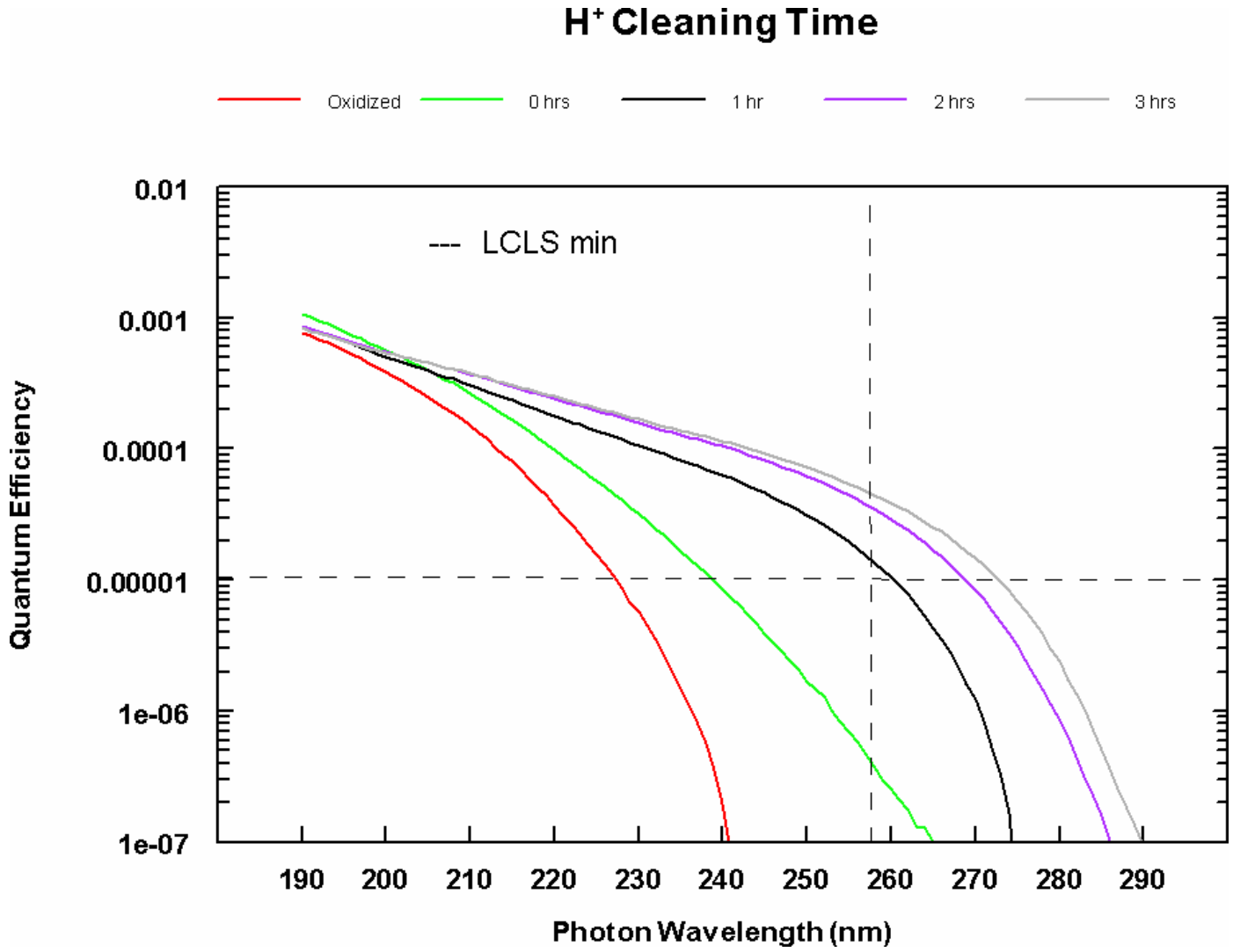
Cathode Qualification System





- Measures either GTF or LCLS-style cathodes
- Ion-cleaning, XPS/AES, QE

LCLS Cathode#1 Qualification (in CQS)



H_2-brazed, diamond fly cut, vacuum fired at 650C for 24 hours

Other Cleaning Stategies

- Laser heating (sometimes evaporation) was used early and often to clean the cathodes and increase QE

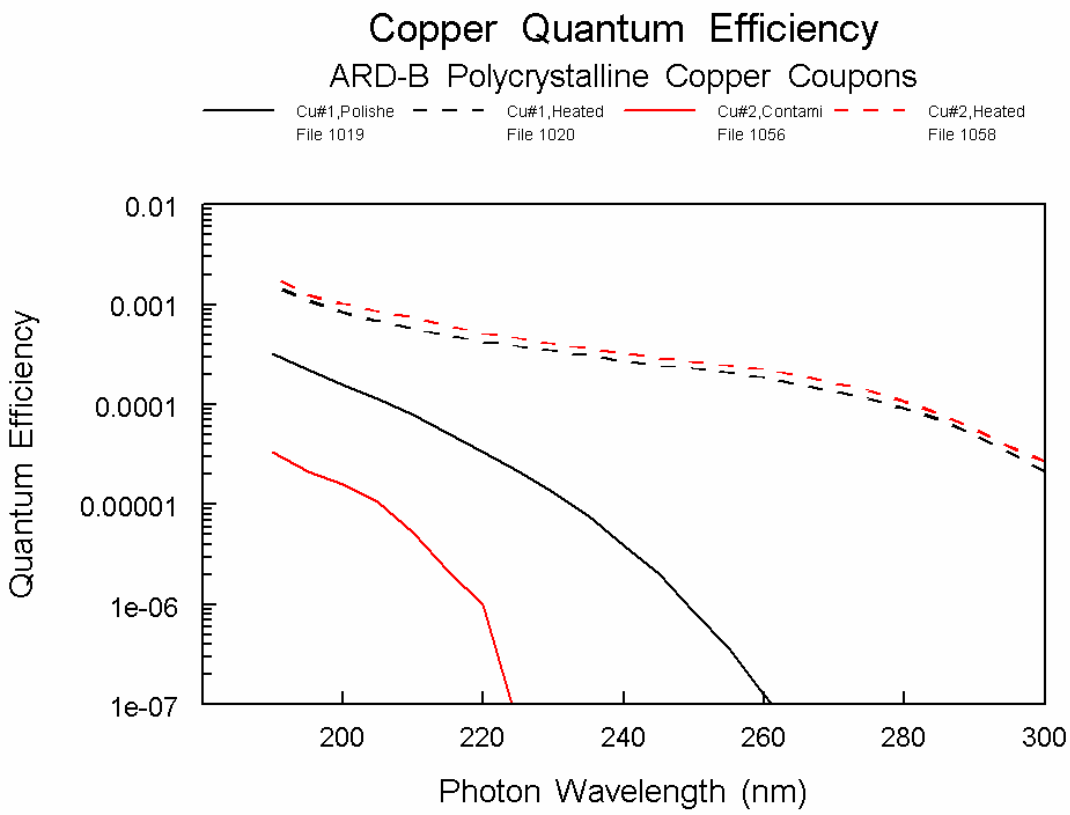
  - Some success but usually the surface was also damaged

- Heat cathode during gun bakeout

  - Only a starting point, usually low QE (< 10^{-5} @ 255 nm) because of hydrocarbon adsorption from gun surfaces
  - GaAs experience says keep cathode hotter than system

- In-gun glow discharge cleaning with H_2 or Ar
  - First results in two guns mixed, QE rise/drop inconsistent
  - Glow appears to be moving contamination around the gun

Cleaning with Heat



Expect wavelength cutoff at 290 nm (Φ=4.5 eV), needs more investigation

Next Investigations

- Make QE area scans in CQS
- Measure QE dependance on polarization
- Monitor QE of cathodes while in vacuum storage
- Heat vacuum-stored cathodes with hot gas through water cooling lines
- Extend R&D coupon studies to connect the exact surface species with QE degradation